THE UNIVERSITY OF TULSA

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GEOMETRY AND ORIGIN OF THE BURBANK SANDSTONE AND MISSISSIPPIAN "CHAT" IN T.25 N., R.6.E. AND T.26 N., R.6.E. OSAGE COUNTY, OKLAHOMA

by

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A THESIS

APPROVED FOR THE DEPARTMENT OF GEOLOGY

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ABSTRACT

The geometry, stratigraphic relationship and origin of the Burbank sandstone and Mississippian "chat" in the subsurface of T.25 N., R. 6 E., and T.26 N., R.6 E., Osage County, Oklahoma, are discussed in this paper.

From subsurface data collected from electric logs a series of isopach maps and stratigraphic cross sections "hung" from a thin limestone bed were prepared to show their geometry and stratigraphic relationships.

It is found that the Burbank sandstone bodies in the thesis area form part of a series of chenier, beach ridges, barrier islands, and spits deposited in the western shore of the Cherokee sea.

The Mississippian "chat" filled in the topographic lows. Probably some is in the form of channels but some is more residual in character. Its components although of Mississippian origin were reworked, redistributed and recemented by Pennsylvanian seas.

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INTRODUCTION

Location of the Area

The sedimentary rocks discussed in this paper are those found in the subsurface of T. 25 N., R. 6 E., and the south of T. 26 N., R. 6 E., Osage County, Oklahoma (Plate 1).

Six oil fields are partially or entirely included in the area: West Little Chief, North Burbank, Stanley Stringer, South Burbank, Fairfax, and East Little Chief.

Purpose of Study

The present investigation had as its major purpose the detailed study of the sandstone bodies occurring in the "Cherokee" shale of the Desmoinesian Series of Middle Pennsylvanian age, in order to determine their geometry-shape, size, and orientation--their stratigraphic relationships, and finally to draw conclusions regarding depositional environment by comparison with analogous distributional patterns of recent sediments.

Previous Work

The Osage County area is one of the most famous oil-producing regions in the world. Extensive subsurface geologic work has been done and published on the geology of the sandstone bodies occurring in the "Cherokee" shale of this area and surrounding parts of northeastern Oklahoma and southeastern Kansas. The lenticular character of these sandstones was recognized as early as the middle 1910's. Shannon (1915) suggested the possibility of oil accumulation in lenses in the Pennsylvanian rocks north of the Arkansas River. Gould (1915) recorded discoveries of "prolific oil and gas pools in thick lenses of sandstone in Carboniferous strata." Robinson (1919, 1922) stated the possibility of obtaining gas and oil from lenticular sands in the area of Osage County. Since then several more papers have been written referring to the close relationship of oil accumulation and lenticularity of the "Cherokee" sandstones. Some of them have suggested off-shore bars as their origin.

Of these works, perhaps the most complete and most closely related to the area in question are those by Bass (1936); Bass, Leatherock, Dillard, and Kennedy (1937); and Bass, Goodrich, and Dillard (1942). In these papers the authors discuss the size, orientation, physical properties, and origin of the Burbank and Bartlesville sandstones and reached the conclusion that these sandstone bodies "are large lenses which were probably deposited as a system of off-shore sand bars on the western shore of the Cherokee sea."

In the last decade the Shale Shaker has compiled in three Digests (I, 1952-1955; II, 1955-1958; III, 1958-1961) a series of M.S. theses from the University of Oklahoma dealing mainly with subsurface geology in parts of Oklahoma. In most of them, problems of correlation of the "Cherokee" rocks are discussed, as well as the paleogeology and historical geology of Osage County and, in general, of northeastern Oklahoma.

Baker (1962) describes the general petrography of the non-reservoir facies included in the "Cherokee" Group in the Burbank field, Oklahoma, and Thrall field, Kansas. This paper discusses the organic character and potential of the shales as source rocks of petroleum.

NOMENCLATURE AND CLASSIFICATION

Oakes (1953, pp. 1523-1526) divided the lower part of the Desmoinesian Series into the Cabaniss and Krebs Groups. In 1954, the Oklahoma Geological Survey (Branson, 1954, p. 1) dropped the term "Cherokee" from formal stratigraphic nomenclature and replaced it with the Cabaniss and Krebs Groups. Hereafter in this paper the term "Cherokee" will be used in quotation marks. The name of "Key" limestone is given in this paper to a thin bed of limestone about 32 feet above the Pink limestone and in the zone of the lower Skinner sandstone. The name of Mississippian "chat" is given to the chert conglomerate found at the base of the Pennsylvanian sediments. Figure 1 illustrates the electric log characteristics and the classification of the subsurface rocks in the interval discussed in this paper.

GENERAL GEOLOGICAL SETTING OF THESIS AREA

Stratigraphy

Studies made by the geologists of the State Geological Survey of Kansas, the Oklahoma Geological Survey and others such as Moore (1944, 1949, 1951); Oakes (1953); Searight (1953, 1958); Branson (1954, 1957); Howe (1956); Baker (1962); and by a series of MS theses from the University of Oklahoma published in Digests I, II, III, of the Shale Shaker (1950-1961) demonstrate that the "Cherokee" includes a variety of different lithologic types such as sandstone, siltstone, underclay, coal, greenish gray shale, gray shale, black shale, and limestone. This variety of lithologies indicates that the sediments of the Cabaniss and Krebs Groups were deposited under more than one sedimentary environment which fluctuated from non-marine to marine.

A type log and the nomenclature and classification of these rocks as used in the thesis area is given in figure 1.

The most significant markers on the electrical logs of this section are the base of the Oswego limestone, the Verdigris Limestone, the "Key" limestone, the Burbank sandstone, the Mississippian "chat" and Mississippian limestone. The Pink limestone is a good marker only in the south half of the T. 25 N., and is poorly developed in the rest of the area. The Inola limestone is not clearly marked on the electrical logs. It is only identified in logs where the Burbank sandstone is absent. The Prue sandstone and the Lower Skinner sandstone are also identified. The Mississippian "chat", which is easily identifiable by its low resistivity and high negative spontaneous potential, is found resting unconformably on the Mississippian limestone principally in T. 25 N. Its thickness varies from 0 to 100 feet.

Petrography

In contrast to the large number of published reports on the "Cherokee" stratigraphy and correlation, there are relatively few reports on the petrography of the shales, sandstones, and limestones of this interval in northeastern Oklahoma.

Non-Reservoir Rocks

Baker (1962) distinguishes three types of shales: greenish gray, gray, and black. The greenish gray and gray types are composed chiefly of quartz, chlorite, and sericite. Siderite as a common minor mineral is found in the greenish gray type as well as opaque shreds of organic matter. A limited marine fauna is reported in some places. The gray shales contain a significant amount of opaque shreds of organic matter and some pyrite. Carbonized plant remains and marine fossils are common. The greenish gray type is generally silty.

The black shales are composed mostly of quartz, illite, some chlorite, and relatively abundant pyrite, and opaque shreds of organic matter. Phosphatic nodules are present. Conodonts and orbiculoid brachiopods are reported as common fossils. Texturally the black shale is a clay shale with excellent fissility. The underclay is usually olive-gray in color and is composed mostly of quartz and clay minerals. Pyrite, ankerite veins and segregates, and some limestone nodules are reported common as well as carbonized plant remains.

Limestones are generally light to medium gray in color. Most of these are biomicrites, following Folk's (1959) classification.

Sandstone

Cores and well cuttings from the Burbank sandstone, examined under the binocular microscope reveal no textural or compositional differences between the various sandstone bodies. They are composed mainly of angular to subangular quartz grains that range in size from very fine to medium. Minor amounts of mica and traces of feldspar, zircon, chlorite, glauconite, hornblende, rutile, magnetite, pyrite, and epidote are recorded by Leatherock (1937).

Mississippian "Chat"

The term "Mississippian chat," as used in this paper, designates the chert conglomerate found in the lowermost portion of the "Cherokee" interval. This conglomerate consists of weathered, tan, sandy, tripolitic chert fragments cemented by silica. The fragments are angular to subangular. A green silty shale matrix is reported in some core analysis reports. The "Chat" normally has a high porosity (10 to 40 per cent), and permeability.

Structure

Since an excellent structural evaluation of Osage County is included in the work published in U. S. Geological Survey Bulletins 686 and 900, this subject is not discussed in this paper. Several detailed maps are available at the Osage Indian Agency at Pawhuska. The Oswego limestone, present over the entire county, is the key bed picked by the early drillers. It is the best Pennsylvanian structural marker. The regional dip of the rocks in the thesis area is westward at the rate of 35 feet to the mile, as measured on the top of the Oswego limestone.

Tectonic Framework of Sedimentation

This paper discusses only that part of the Pennsylvanian tectonic framework which is directly related to the deposition of the Desmoinesian rocks in northeastern Oklahoma and southeastern Kansas. The tectonic framework of sedimentation is understood, as defined by Krumbein and Sloss (1955, p. 318), as the combination of subsiding, stable, and rising tectonic elements in the sedimentary source and depositional areas. Tectonic elements active in Pennsylvanian time in this area were: the Nemaha ridge, the Bourbon arch, the Ozark dome, the Ouachita geosyncline, and the Cherokee basin.

In Early Pennsylvanian time southern Oklahoma underwent extensive folding and faulting. The Ouachita geosyncline was uplifted and the Arkoma basin became depressed. The Anadarko basin was formed essentially at this time. The Nemaha ridge trending southwest from Omaha through southeastern Nebraska across Kansas into northern Oklahoma came into mountainous relief at this time and separated the Anadarko basin to the west from the shallow Cherokee basin to the east (Figure 2).

Slightly north of the site of the Devonian Chautauqua arch in east central Kansas the Bourbon arch was uplifted. It was probably a shallow platform between the Forest City basin on the north and the Cherokee basin on the south, and connected the Nemaha ridge with the Ozark dome which appeared to the east of the area as an emergent land mass. Slight subsidence of the basins took place and the oscillating Pennsylvanian seas transgressed northward on the eroded pre-Pennsylvanian surface. At the time of the deposition of the "Cherokee" rocks the generalized paleogeography included the Ozark dome, Ouachita geosyncline, and Nemaha ridge as positive areas separated by shallow seas (Figure 2).

CORRELATION OF "CHEROKEE" GROUP

A total of about 1220 wells have been drilled in the area in search for oil or gas. Records from about 70 per cent of these wells were used in this investigation. They show that the strata between the base of the Oswego Limestone and the top of the Mississippian limestone vary in thickness from approximately 220 feet at the north to 300 feet at the south of the area.

Subsurface data was obtained from electrical, sample, and driller's logs obtained from the Oklahoma Well Log Information Service, Tulsa, and from the Osage Indian Agency in Pawhuska. Sample and driller's logs were used where no other kind of information was available.

Some cores and rotary samples from the different sandstone bodies were examined for correlative checks with electric logs. The top and bottom of the Burbank sandstone were determined principally from the SP curve. When the sand-shale contact was not clearly defined on the SP curve because of the shaly condition of the sand, the top of the sand was arbitrarily picked at 40 mv. above the shale-base line.

The correlation network was set up on three distinctive units: the base of Oswego Limestone, the "Key" limestone, and the Pink limestone. All three units present a characteristic mark on the electrical logs useful for correlation. Some difficulty was encountered in the identification of the Pink limestone in the north part of the area.

In the choice of a datum plane for the purpose of this study the following characteristics were taken in consideration:

1 - It should be a good marker on the electrical logs and consequently easy to recognize and correlate throughout the entire area.

2 - The datum plane should be a non-transgressive unit, of essentially simultaneous deposition, at least in the area of study.

3 - The datum plane must be close enough to the sandstone bodies so that geologic events occurring between the deposition of the sandstone bodies and the deposition of the datum plane unit may not

obscure their original relationship.

The only unit found to fill this requirements was an unnamed limestone which is three to four feet thick and is widespread over the area. It lies about 70 feet below the base of Oswego limestone. It is called the "Key" limestone.

The interval from the "Key" limestone to the top and bottom of the main productive sandstone, and to the top of the Mississippian "chat" and Mississippian lime were calculated and recorded on a base map (Plate 1).

However, when sample and driller's logs were used, the "Key" lime stone can not be recognized. In this case the base of the Oswego limestone was taken as the reference plane for the calculations of the above mentioned tops. From electric logs it was found that the interval from the base of the Oswego limestone to the top of the "Key" limestone ranges between 70 and 80 feet. This interval does not vary more than four feet in a square mile section and no more than 10 feet over the entire area. The position of the "Key" limestone can therefore, be determined with an accuracy of four feet or less by adding the appropriate interval to the base of the

Oswego limestone.

On the basis of the data collected and recorded on the base map (Plate 1) six isopach maps were contoured (Plate II, III, IV, V, VI, and VII). These isopach maps define the size and orientation of the sandstone bodies and the Mississippian "chat," but only partially depict their shape. Therefore, in order to determine and portray their shape stratigraphic cross-sections of Plate VIII were constructed using the top of the "Key" limestone as a datum.

GEOMETRY OF THE BURBANK SANDSTONE BODIES

In the "Cherokee" interval, four significant, elongate, lenticular sandstone bodies have been detected in the subsurface. The thickness of the sandstone bodies recorded by the well logs ranges from 0 to 90 feet. The four sandstone bodies have been found to be stratigraphic equivalents of each other (Plate VIII). They represent the Burbank sandstone in the columnar stratigraphic section of the area.

In order to reconstruct as closely as possible the original geometry of the sandstone bodies isopach maps and stratigraphic cross sections "hung" from the "Key" limestone have been prepared from the data collected on the base map.

The geometry of a sand body implies the definition of the shape, size, and orientation. Shape involves more than three dimensions--length, width, and thickness-- a prism and a lens might have these dimensions in common, but they are quite different in shape. Because a sandstone body of the same shape may differ in size, this is also a factor that must be determined. The third factor, orientation or trend, is also important not only from the point of view of origin but also in the development of an oil field.

Size and orientation of the particular Burbank sandstone bodies in this area are well defined on Plates II, III, and IV. Plate II is the isopach of the interval from the "Key" limestone to the top of the sandstone and it gives a clear picture of the upper surface of the sandstone bodies. Plate III which represents the thickness of the interval from the "Key" limestone to the bottom of the sandstone bodies shows the characteristics of the lower surface. Plate IV, an isopach of the sandstone bodies, gives a clear idea of their size.

The shape and stratigraphic relationship of the four main sandstone bodies are also shown by the stratigraphic cross sections on Plate VIII.

The geometry of a sandstone body has environmental implications. The following measurable

criteria can be of help in trying to decide
environmental interpretation is better in
case:

1) Proximity to another sand body
2) Orientation with respect to other sandstone bodies
3) Orientation with respect to depositional strike
4) Cross section
5) Relief of the upper and lower surfaces
6) Stratigraphic relationship to the surrounding strata.

Applying these criteria to the choice of an environment of deposition of the sandstone bodies in this area, the following facts are brought forth in Plates II, III, IV, and V.

1) Boundaries are abrupt. The thickness of permeable sandstone can increase from 0 to more than 80 feet in a horizontal distance of less than 500 feet.

2) There is a smooth eastern boundary in contrast with an irregular western boundary. Many interfingerings of shale into the main sandstone body are observed along the western boundary.

3) A more irregular complex relief is shown by the upper surface than by the lower surface, which is essentially flat.

4) Ridges trending parallel to the boundaries of the sandstone bodies are shown by the relief of the upper surfaces.

5) The pattern is often bifurcated. A sandstone body branches off in more than two arcuate sandstone bodies.

6) There is an orientation approximately parallel to the assumed depositional strike.

7) The cross sectional shape is plano-convex. A slightly biconvex shape could be attributed to compaction.

8) There is lateral stratigraphic equivalency.

All of the above facts observed on the maps define the geometry of the sandstone bodies. Implications of this geometry with respect to the origin of the sandstone bodies are discussed further on in this paper.

GEOMETRY AND DISTRIBUTION OF THE MISSISSIPPIAN "CHAT"

At the base of the rocks of the "Cherokee" interval is found the Mississippian limestone and the Mississippian "chat." The distribution and thickness of the Mississippian "chat" are shown by Plates V and VI. The "chat" is present mainly in T. 25 N. and in a relatively few places in T. 26 N.

Plate VII, the isopach of the interval from the "Key" limestone to the top of the Mississippian limestone, was prepared to show the relief on the Mississippian-Pennsylvanian unconformity. This map can be considered a paleotopographic map of the pre-Pennsylvanian surface.

The most significant feature that becomes apparent when these three maps (Plates V, VI, and VII) are compared is the similarity between the distributional pattern of the Mississippian "chat" and that of the Mississippian paleotopography. The Mississippian "chat" fills the topographic lows of the Mississippian unconformity surface. This is also apparent in the cross sections in which the flat top and the convex downward lower surface, characteristic of channel filling deposits, are shown.

ENVIRONMENTS OF DEPOSITION

Burbank Sandstone Bodies

Considerations stated before leave little doubt that the Burbank sandstone bodies belong to the near-shore facies and were deposited in an oscillating but generally transgressive condition.

The oscillating nature of the "Cherokee" sea was recognized by early authors. Bass (1937) refers to the oscillating nature of the sea "across a relatively narrow northeast trending strip of country in eastern Osage, Washington, and Nowata counties, Oklahoma, and southeastern Kansas." Under this condition a series of sediments representing non-marine to marine environments were deposited. The pattern developed in this sequence is similar to that of the cyclothems described by Weller (1930, 1931, and 1957) and Wanless (1955, 1957) in the Illinois basin. The Burbank sandstone bodies are believed to represent the transitional facies deposited on or near the shoreline.

The transgressive condition of this sea is shown by the thickening southward of the "Cherokee" strata below the "Key" limestone. This feature is clearly depicted by isopach maps of the "Cherokee" group in a more regional extent (Bass, 1936, and Weirich, 1953). Cross sections of the area show onlap of the "Cherokee" strata on the eroded Mississippian rocks.

If the above consideration is accepted two possible origins are suggested by the linearity of these sandstone bodies and their relationship to the enclosing strata:

a) Non-meandering river or delta distributary;

b) Chenier, beach ridge, spit or barrier island.

The shoreline trend in the area suggested by the trend of the contour lines of the "Cherokee" isopach maps is north-northeast. The trend of the sandstone bodies under consideration is also north-northeast. This fact suggests that the non-meandering river or delta distributary possibility should be rejected since sandstone bodies of this type have their long axis perpendicular to the shoreline.

Although these sandstone bodies are somewhat thicker than the average of modern chenier deposits described by Gould and McFarland (1959), they show a marked similarity in many other features. Features common to both Burbank sandstone bodies and chenier deposits are: (1) a smooth seaward margin; (2) an irregular outline on their landward margin; (3) a plano-convex or faintly biconvex cross sectional shape; (4) a fine to very fine sand size; (5) well sorted sands; (6) parallelism to the shoreline; and finally (7) the bifurcated pattern displayed by both.

The stratigraphic equivalence displayed by the four Burbank sandstone bodies is also found in modern barrier islands. Bernard (1959) reports adjacent chains of barrier islands deposits along the Texas and Mexican coast occurring in the same "stratigraphic" position. In places they are adjacent to each other and in others they are separated by lagoonal or marine deposits.

Ridges displayed by the upper surface (Plate II) are similar to those beach ridge growths observed in modern barrier sands.

Transverse depressions observed in Plate II across the upper surface may indicate tidal inlets similar to those developed in modern barrier sand deposits.

Mississippian "Chat"

The Mississippian "chat" filled in the topographic lows. Probably some was deposited in the form of channels but some might be more a residual material winnowed by the waves of the advancing sea. This is the only choice for its origin left after analysing the clear relationship between the Mississippian paleotopography and the distribution of the Mississippian "chat" depicted by Plate V, VI, VII. The typical flat top and convex downward lower surface of channel filling deposits is clearly developed by the Mississippian "chat" deposits in some parts of the area, as shown in the stratigraphic cross sections (Plate VIII).

HISTORIC DEVELOPMENT

During the tectonic movements of early Pennsylvanian the Mississippian rocks, mostly chert and cherty limestone, were uplifted and exposed to erosion and weathering. The product of weathering of these rocks is believed to be the chert fragments now found in the Mississippian "chat." They possibly formed a regolith over the entire flat area of the Cherokee basin.

Erosion was much stronger on the highest part of the uplifts. Up to 15,000 feet of pre-Pennsylvanian sedimentary rocks covering the granitic basement of the Arbuckle mountains and Nemaha ridge was removed.

During the Middle Pennsylvanian the sea transgressed over the area in a northwest direction. The chert fragments were reworked, redistributed and concentrated in the topographic lows and later recemented to form the chert conglomerate known today as the Mississippian "chat."

At this time the picture presented by the area was that of an extensive tidal flat of very low seaward gradient over which the sea would advance, stand, and retreat many times. During one of the standing sea level stages, sands were deposited as cheniers, beach ridges, barriers, and spits in the vicinity of local embayments.

Under these conditions the sandstone body found in the West Little Chief oil field began as a small bar which later emerged as an island and grew seaward (eastward) by beach accretion. Then the Burbank field sandstone body, which was separated from the former by tidal flat sediments was born and grew by beach accretion. Finally, the Stanley Stringer, South Burbank, and East Little Chief were born as spits tied to the Burbank field sand and grew southward by accretion in the direction of the prevailing longshore drift.

CONCLUSIONS

From the preceeding discussion the following conclusions are inferred:

1. The components of the Mississippian "chat," although of Mississippian origin, were reworked, redistributed, and recemented by the Pennsylvanian seas.
2. The Mississippian "chat" filled in the topographic lows. Probably some is in the form of channel filling deposits but some is more residual in character.
3. The Burbank sandstone bodies in this area form part of a series of cheniers, beach ridges, barrier islands, and spits. They were developed during one of the many standing sea level stages of the transgressive "Cherokee" sea.
4. The landward side in the area is to the west. The sea transgression occurred from the southeast to the northwest.
5. The oldest Burbank sandstone body is that found

in West Little Chief field. Progradation to the east originated the adjacent sandstone bodies in the same stratigraphic position. These are found in the Burbank, Stanley--South Burbank, and (East ?) West Little Chief fields.

6. The Stanley Stringer- South Burbank sandstone body originated as a spit tied to the Burbank sandstone body. Accretion to the south in the direction of the longshore currents of the time gave it a narrow elongate shape.

7. The youngest of the four sandstone bodies, the one found in the East Little Chief field, was developed by the same process that developed the Stanley Stringer - South Burbank sandstone body. This time the East Little Chief sand body was tied to the Stanley Stringer- South Burbank.